

Septodont Case Studies *Collection*

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Focus on Biodentine

A NEW BIOACTIVE CEMENT

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Editorial



Since its foundation Septodont has developed, manufactured and distributed a wide range of high quality products for dental professionals.

Septodont recently launched innovations in the field of gingival preparation, composites and dentine care with the introduction of Racegel, the N'Durance® line and Biodentine™, which are appreciated by clinicians around the globe.

Septodont created the “Septodont Case Studies Collection” to share their experience and the benefits of using these innovations in your daily practice.

This Collection is a series of case reports and will be published on a regular basis.

This first issue is dedicated to Biodentine™, the first biocompatible and bioactive material to be used wherever dentine is damaged. Biodentine™ uniqueness not only lies in its innovative bioactive and “pulp-protective” chemistry, but also in its universal application, both in the crown and in the root.

The case studies featured in this issue present its clinical benefits for the multiple indications this dentine substitute has been designed for: restorative dentistry, paediatric dentistry and endodontics.

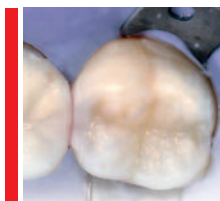
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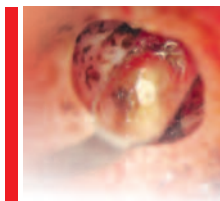
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Biodentine™

a new bioactive cement for direct pulp capping

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Summary

Biodentine™ is a new bioactive cement with dentin-like mechanical properties, which can be used as a dentin substitute on crowns and roots. It has a positive effect on vital pulp cells and stimulates tertiary dentin formation. In direct contact with vital pulp tissue it also promotes the formation of reparative dentin. This prompted its use for direct pulp capping after iatrogenic pulp exposure at tooth 15 in a 22-year-old male patient. First the entire cavity was filled with Biodentine™. Three months later the cement was reduced to a base to replace the dentin layer and a composite filling was placed to

replace the enamel layer. At the follow-up visit at 6 months the tooth was clinically normal and tested positive for sensitivity and negative for percussion. The dental film showed the apical region without any pathological findings.

Due to its improved material properties, Biodentine™ is an interesting alternative to conventional calcium hydroxide-based materials. It offers advantages for direct pulp capping and, in properly selected cases, may contribute to the long-term maintenance of tooth vitality.

Introduction

For many decades calcium hydroxide has been the standard material for maintaining pulp vitality. Both clinically and histologically it has been found to produce satisfactory results in indirect and direct pulp capping, because it is capable of stimulating the formation of tertiary dentin by the pulp. In contact with vital pulp tissue it contributes to the formation of reparative dentin, a special variant of tertiary dentin, which seals exposures by newly formed hard tissue. This has been documented by basic research and clinical studies with reported success rates in excess of 80 % for direct pulp capping [1, 2]. Currently, calcium hydroxide

products are the best documented and most reliable materials for direct pulp capping and serve as the “gold standard” against which new materials have to be tested [3].

Nevertheless, calcium hydroxide has some drawbacks. Poor bonding to dentin, material resorption and mechanical instability are among them. As a result, calcium hydroxide does not prevent microleakage in the long run. The porosities (“tunnel defects”) of the newly formed hard tissue may act as a portal of entry for microorganisms. These may cause secondary inflammation of the pulp tissue and are thought

to be responsible for failed maintenance of tooth vitality. In addition, the high pH (12.5) of calcium hydroxide suspensions causes liquefaction necrosis at the surface of the pulp tissue [1].

A new bioactive cement, Biodentine™ (Septodont, St. Maur-des-Fossés, France), was recently launched on the dental market as a dentin substitute. It shares both its indications and mode of action with calcium hydroxide, but does not have its drawbacks. Biodentine™ consists of a powder in a capsule and liquid in a pipette. The powder mainly contains tricalcium and dicalcium silicate, the principal component of Portland cement, as well as calcium carbonate. Zirconium dioxide serves as contrast medium. The liquid consists of calcium chloride in aqueous solution with an admixture of polycarboxylate. The powder is mixed with the liquid in a capsule in the triturator for 30 seconds. Once mixed, Biodentine™ sets in about 12 minutes. During the setting of the

cement calcium hydroxide is formed. The consistency of Biodentine™ reminds of that of phosphate cement.

Biodentine™ can be used both on crowns and roots. Its crown uses include pulp protection, temporary closure, deep caries management, cervical filling, direct and indirect pulp capping and pulpotomy. On roots it has a place in managing perforations of root canals or the pulp floor, internal and external resorption, apexification and retrograde root canal obturation.

In summary, Biodentine™ is both a dentin substitute base and a cement for maintaining pulp vitality and stimulating hard tissue formation, i.e. the formation of reactive or reparative (tertiary) dentin.

The case report illustrates the use of Biodentine™ for direct pulp capping.

Case report

Four years ago a male patient, then 18 years old, came for a routine check-up. Bitewing films recorded during the diagnostic assessment showed signs of an approximal carious lesion distally on tooth 15 (*Fig. 1*). The patient was informed about the need of having the carious lesion treated, but failed to show up at the scheduled appointment. At age 22 he came back complaining of discomfort of tooth 15

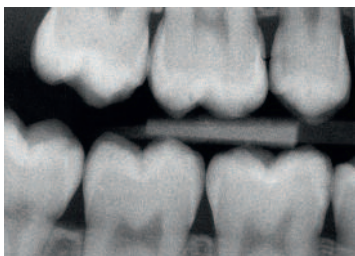


Fig. 1: Bitewing film of quadrants 1 and 4 of a patient aged 18 years at the time. Note the proximal carious lesion on tooth 15 distally. The patient did not show up at the scheduled appointment for filling.



Fig. 2: When the patient returned 4 years later, iatrogenic pulp exposure occurred at two sites during complete caries excavation.

upon contact with cold food, drinks and air apparently caused by a buccal enamel fracture of tooth 15. On examination, a deep approximal carious lesion was found distally. The tooth was tested positive on CO₂ snow sensitivity and negative on percussion. After thorough information of the patient, an anesthetic (Septanest, 1 ml; Septodont, St. Maur-des-Fossés, France) was injected for terminal anesthesia and a rubber dam was put in place. Following cavity preparation the carious dentin was completely excavated. In the process the pulp cavity was exposed iatrogenically at two sites (*Fig. 2*). Clinically the pulp tissue was vital without any major bleeding, so that maintenance of tooth vitality by direct pulp capping was decided upon. Cavity toilet with NaOCl (2.5%) was done for hemostasis, clearing and disinfecting the cavity. Biodentine™ (Septodont, St. Maur-des-Fossés, France)

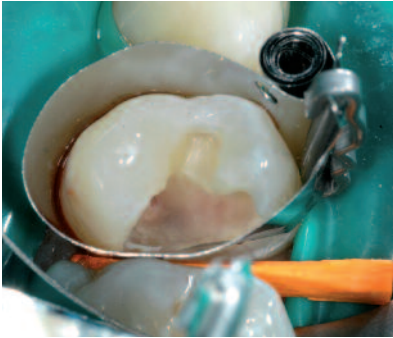


Fig. 3: For filling the cavity and for direct capping with Biodentine™ (Septodont; St. Maur-des-Fossés, France) a matrix band (AutoMatrix; Dentsply-Caulk, Milford, DE, USA) and wedges were put in place.



Fig. 4: Biodentine™ was applied to the cavity with cement pluggers using light pressure. Carving instruments were used for occlusal adjustment. Biodentine™ should not be prepared with rotating instruments and should not come into contact with water.



Fig. 5: After allowing 12 to 15 minutes for Biodentine™ to set the bite was checked. Subsequent polishing of the Biodentine™ filling should be omitted.



Fig. 6: Three months later the patient returned to have the cavity definitively filled with composite. At this visit the Biodentine™ filling showed marginal material loss.



Fig. 7: Biodentine™ reduced to a base/dentin substitute level.



Fig. 8: Before restoring the cavity with composite a matrix band (Composi-Tight 3D; Garrison, Spring Lake, MI, USA) and wedges were put in place.

was chosen for direct pulp capping. Mixed as recommended by the manufacturer, Biodentine™ was applied to the exposed pulp tissue for direct capping and for temporary restoration so that the entire cavity was filled with the bioactive cement (*Fig. 4*) after placing a matrix band (AutoMatrix; Dentsply-Caulk, Milford, DE, USA), (*Fig. 3*). About twelve minutes after mixing, i.e. after Biodentine™ had set, occlusion was checked (*Fig. 5*). At the follow-up visit 4 days after direct capping the patient reported some increased cold and warm sensitivity of tooth 15, but no other subjective symptoms.

Three months after direct capping he returned for having the Biodentine™ filling (*Fig. 6*) partially removed and topped by a composite filling to replace enamel. The symptoms he had originally reported had completely disappeared

within a very short time. Tooth 15 was clinically normal and tested positive for sensitivity and negative for percussion. An anesthetic (Septanest, 1 ml; Septodont, St. Maur-des-Fossés, France) was injected for terminal anesthesia and a rubber dam was placed. The Biodentine™ filling was reduced and kept as a base/dentin substitute (*Fig. 7*) and a matrix band as well as wedges (Composi-Tight 3D; Garrison, Spring Lake, MI, USA) were applied (*Fig. 8*). Then the entire cavity was etched with phosphoric acid, a dentin adhesive (Optibond FL; Kerr, Orange, CA, USA) and a composite (Grandio; VOCO, Cuxhaven, Germany) was applied (*Figs. 9 and 10*). At the follow-up visit 6 months after direct capping tooth 15 was clinically normal and again tested positive for sensitivity and negative for percussion. The dental film recorded at that time did not show any pathological findings apically (*Fig. 11*).

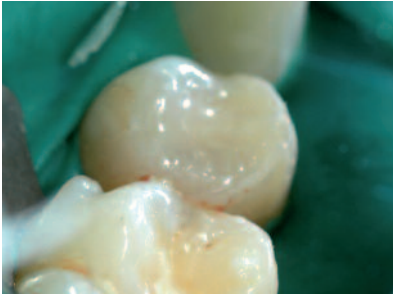


Fig. 9: Cavity filled with composite (Grandio; VOCO, Cuxhaven, Germany).

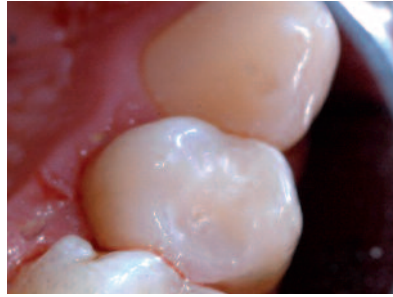


Fig. 10: Finalized and polished composite filling.

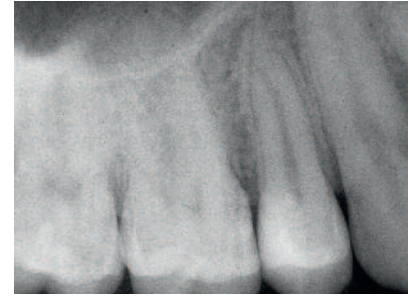


Fig. 11: The dental film recorded 6 months after direct capping does not show any pathological findings apical of tooth 15.

Discussion

Biodentine™ was shown to be biocompatible, i.e. it does not damage pulpal cells in vitro or in vivo, and is capable of stimulating tertiary dentin formation. Hard tissue formation is seen both after indirect and direct capping with Biodentine™ [4 - 6]. Used for pulp capping, the material offers some benefits versus calcium hydroxide: It is stronger mechanically, less soluble and produces tighter seals [7]. This qualifies it for avoiding three major drawbacks of calcium hydroxide, i.e. material resorption, mechanical instability and the resultant failure of preventing microleakages.

Compared to other materials (e.g. Mineral Trioxide Aggregate), Biodentine™ handles easily and needs much less time for setting. Unlike other Portland cement-based products, it is sufficiently stable so that it can be used both for pulp protection and temporary fillings [7]. This is why the manufacturer recommends to fill the entire cavity completely with Biodentine™ in a first step and to reduce it to a base/dentin substitute level in a second visit one week to 6 months later before definitive restoration. For successful capping it is, however, important to seal the cavity against bacterial invasion in a one-stage procedure [2, 8]. While there is extensive evidence documenting that composite fillings are leak-proof, few pertinent data are available for Biodentine™. Another argument against the two-stage procedure recommended by the manufacturer is the uncertain cooperativeness of

patients: will or will they not show up for a second visit [9]? Add to all this that the inevitable repeated cavity preparation during the second visit exposes the pulp tissue, damaged as it already is by prior direct capping, to more stress. This can be avoided by a single-stage approach. Consequently, studies are underway to find out whether a single-stage procedure is feasible, i.e. applying Biodentine™ for pulp capping or pulp protection and placing a filling (e.g. a composite) for permanent restoration during one visit. When opting for this approach it is, however, important to wait for Biodentine™ to set (about 12 to 15 minutes after mixing) before proceeding with the restorative treatment. Definitive recommendations cannot be made before the results of ongoing studies are available.

Of note, Biodentine™ fillings were found to show marginal material loss at the follow-up visit after 3 months. This may be attributable to an incorrect handling. During occlusal adjustment, Biodentine™ should not be prepared with rotating instruments and should not come into contact with water. It should rather be applied into the cavity with cement pluggers using light pressure, and carving instruments should be used for occlusal adjustment. Subsequent polishing of the Biodentine™ filling should be omitted. Excessive pressure or exaggerated trimming and polishing may disrupt the crystalline structure of Biodentine™ with resultant loss of material strength.

It should be remembered that, aside from the choice of the right capping material, i.e. a material which is biocompatible and capable of stimulating the formation of hard tissue, other factors also play a critical role for direct capping to be successful [2]: (1) The pulp tissue should be clear of bacteria or bacterial toxins. In clinical terms, this means that the tooth should be asymptomatic and that pulp bleeding after exposure should be easily and rapidly controllable. (2) Meticulous hemostasis is indispensable. Blood clots left at the material – pulp interface set the scene for treatment failure [10]. Sodium hypochlorite is an ideal candidate for hemostasis, because it readily controls bleeding, while at the same time disinfecting the cavity [11]. (3) Microbial contamination of the pulp tissue during treatment should be meticulously avoided. This is best achieved with a rubber dam when treating on the dentin third

close to the pulp, which reliably prevents the invasion of microorganisms from the oral cavity or saliva. Preventing microorganisms from entering the pulp is a key factor for successful direct capping [12]. By contrast, patient age and the size or site of pulp exposure at best play a secondary role or are altogether irrelevant [2, 7].

It goes without saying that a follow-up time of 6 months is much too short for evaluating the long-term success of a capping material. Problems associated with direct capping tend to occur up to 5 years post treatment. In more than 50 % of the problem cases direct capping fails within the first two years. Teeth still vital five years after direct capping stand a good chance of retaining their vitality [8]. More long-term clinical studies are, therefore, needed for a definitive evaluation of Biodentine™.

Conclusion

Biodentine™ is an interesting and promising product, which has the potential of making major contributions to maintaining pulp vitality

in patients judiciously selected for direct pulp capping.

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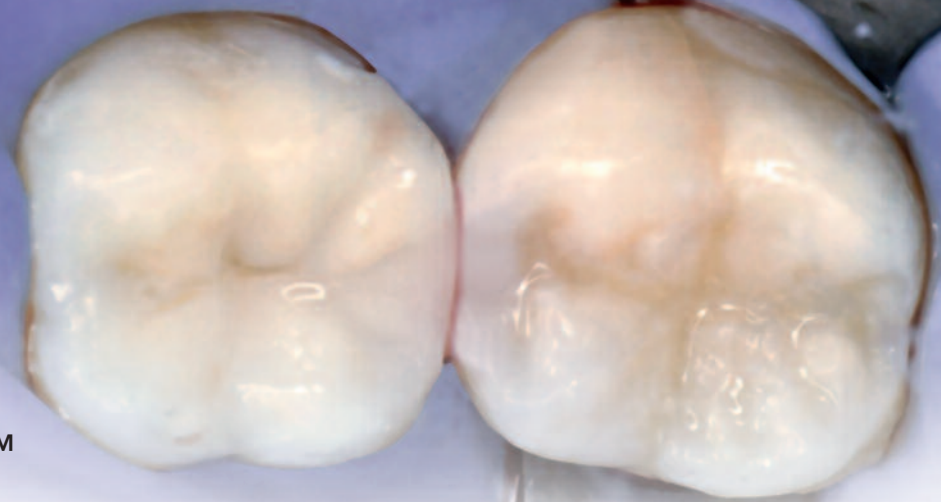


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2008. Aside from the maintenance of pulp vitality, he has focused on studying novel excavation techniques and endodontics.

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Biodentine™

a novel dentin substitute for use in paediatric conservative dentistry

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Introduction

Conservative vital pulp therapy in children calls for the use of specific procedures whose objectives differ from the issues encountered in adults:

- it is important for the temporary tooth to remain in the dental arch to preserve the mesiodistal space, the vertical dimension guiding the physiological positionally normal eruption of succedaneous teeth and to prevent the appearance of parafunctions,
- the preservation of pulp vitality in the deciduous dentition is important as a means of avoiding all risks of periapical diseases that could compromise the fate of the permanent tooth,
- preserving pulp vitality in an immature permanent tooth is important for the apexogenesis of the tooth. When the tooth is mature, the therapeutic aims will also be directed towards preserving pulp vitality, especially if the patient is young.

For decades calcium hydroxide has been the only material available in cases of carious, traumatic or therapeutic pulp exposure in order to obtain pulp healing and dentin repair.

Since the mid-1990s, *Mineral Trioxide Aggregate*® (MTA®) has been recognised as the reference material for the conservative pulp vitality treatments such as pulpotomy in temporary teeth and partial pulpotomy in permanent teeth (Caceido et al., 2006; Deery, 2007).

Animal experiments have shown that MTA® induces the formation of dentin “bridges” protecting pulp lesions markedly more effectively than that observed with calcium hydroxide (Faraco and Holland, 2001; Nair et al., 2008). According to various hypotheses, MTA®-induced dentinogenesis could be due to this material's capacity to ensure marginal integrity,

to its biocompatibility (Mitchell et al., 1999), its temporarily increased pH, or a combination of these (Torabinejad et al., 1995).

Biodentine™ is a cement of the same class as MTA®: this new calcium silicate-based material exhibits physical and chemical properties similar to those described for certain Portland cement derivatives (Saidon et al., 2003). On the biological level, it is perfectly biocompatible (Laurent et al., 2008) and capable of inducing the apposition of reactionary dentin by stimulating odontoblast activity (Goldberg et al., 2009) and reparative dentin, by induction of cell differentiation (Shayegan et al., 2010). It is in

effect a dentin substitute that can be used as a coronal restoration material (for indirect pulp capping), but can also be placed in contact with the pulp.

Its faster setting time allows either immediate crown restoration (Tran et al., 2008), or to make it directly intraorally “functional” without fear of the material deteriorating.

The purpose of this article is to illustrate the clinical procedure for using Biodentine™ in paediatric dentistry through two clinical cases of a kind frequently encountered in everyday practice and in both of which the issue at stake is to preserve pulp vitality.

Procedure

- 1 After cleaning the tooth and preparing the operative field, the procedure begins with caries removal and, in the case of pulp exposure, total or partial ablation of the coronal pulp, depending on the indication (AAPD, 2009). After rinsing the entire dentin cavity with normal saline solution, pulp haemostasis is achieved using a sterile cotton pellet applied for 2 to 3 minutes.
- 2 Before the Biodentine capsule™ is opened, it is tapped gently on a hard surface to diffuse the powder. Five drops of liquid from the single-dose dispenser are poured into the capsule, after which the latter is placed in a triturator for 30 seconds.
- 3 The material is recovered with the aid of the manufacturer-supplied spatula. Depending on how it is desired to use it, it is possible to place the material inside the cavity with the aid of an amalgam carrier, spatula, or a device such as a Root Canal Messing Gun (Produits Dentaires, Vevey, Switzerland), and to adjust the walls without excessive compression using a plugger or cotton pellet.
- 4 The working time is approximately 6 minutes, during which time the material can be sculpted. Moreover, a few additional minutes' setting time need to be allowed before being able to withdraw the matrix and remove the operative field.

Clinical case 1: Cervical pulpotomy on a temporary tooth (Figures 1-a to 1-i)

The 8-year-old patient presented at the dental surgery with numerous carious lesions, including a severe caries in tooth # 55 (Grade 5 according to the ICDAS classification). This temporary tooth was asymptomatic, but the volume of the invasive caries made pulp exposure seem a likely prospect after caries excavation.

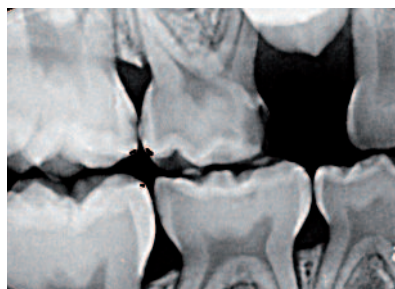
Curettage of the carious lesion under an operative field led to exposure of the mesial pulp horn: the endodontic access was made, the vital pulp was amputated from the chamber by clean section at the entrances to the root canals. The chamber was copiously irrigated with normal

saline solution. After obtaining haemostasis (signifying the absence of any root disorders), the pulp chamber was filled with Biodentine™ (see *Procedure*) until the access cavity was completely filled as far as the occlusal surface. A more durable restoration in the form of a preformed paedodontic cap was put in place one month later.

The therapeutic objective was to preserve pulp vitality at the level of the roots and to prevent the onset of infectious complications at periapical level, in the vicinity of the succedaneous tooth bud.



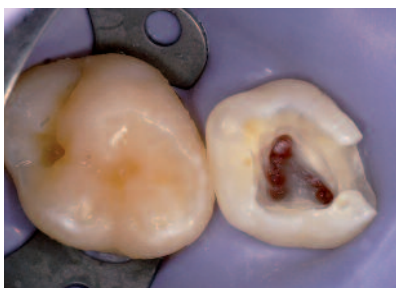
1-a: Initial clinical view



1-b: Initial retro-coronal X-ray image (showing absence of any furcation lesion)



1-c: Isolation of the tooth with the aid of an operative field



1-d: Pulp exposure during the course of caries curettage necessitates carrying out a cervical pulpotomy (vital pulp, non-inflammatory, haemostasis possible)



1-e: Filling the pulp chamber and the coronal cavity with the aid of the Biodentine® material



1-f: Post-operative clinical view



1-g: Post-operative X-ray follow-up



1-h: Delayed placement of a paedodontic cap



1-i: X-ray follow-up image at 3 months showing the absence of any periradicular lesion

Clinical case 2: Partial pulpotomy following pulp exposure during caries curettage on a permanent tooth (Figures 2-a to 2-m)

The 14-year-old patient was referred by her orthodontist for treatment of a carious lesion in tooth # 36, a mature permanent tooth. First of all, an MRI® scan was performed.

After administering nerve block anaesthesia and preparing the operative field, the former restoration was taken out and caries curettage exposed 4 mm of pulp in the distal horn. 2 mm of the inflammatory pulp tissue was removed using a round diamond bur mounted on a high-speed handpiece with irrigation until healthy pulp was reached (haemostasis was obtained). This dentin microcavity was carefully filled with Biodentine™ before proceeding to fill the whole

of the coronal cavity. One and a half months later, the pulp vitality of the tooth and the absence of pulp symptoms were confirmed by testing pulp sensitivity to cold: it was decided to carry out the final crown reconstruction in the form of a ceramic onlay. A part of the cement filling was left in place as a cavity liner on account of the sizable loss of substance; in all cases it is recommended to keep a minimum cement thickness of 2 mm as pulp protection.

The purpose of direct pulp capping (here in the form of a partial pulpotomy) is to encourage pulp healing and to protect the pulp by the formation of a dentin bridge.



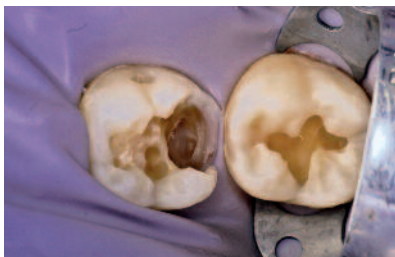
2-a: Initial clinical view



2-b: Retroalveolar X-ray image



2-c: Isolation of the tooth with the aid of an operative field



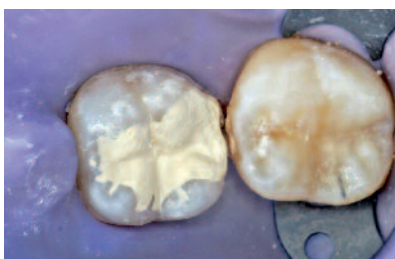
2-d: Removal of restorations



2-e: Pulp exposure during the course of caries curettage necessitates carrying out a partial pulpotomy (vital pulp, non-inflammatory, haemostasis possible)



2-f: Handling the Biodentine® material with the aid of a spatula



2-g: Filling the pulp chamber and the coronal cavity with the aid of the Biodentine® material



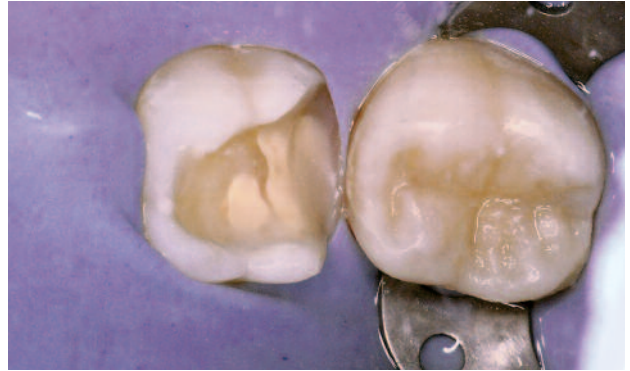
2-h: Post-operative clinical view



2-i: Post-operative X-ray follow-up image



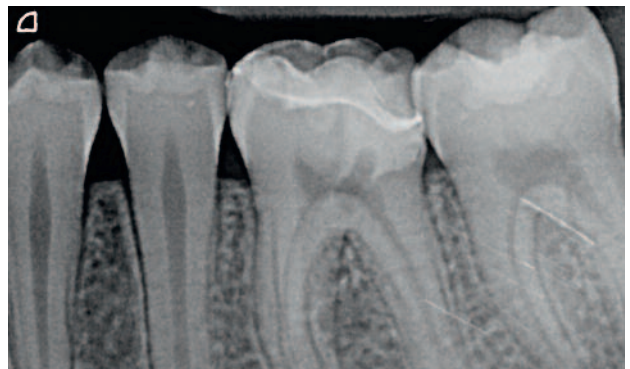
2-j: Clinical view 2 months after Biodentine® application



2-k: Cavity preparation with a view to using an onlay



2-l: Bonding of a ceramic onlay, final restoration



2-m: Clinical view 2 months after Biodentine® application

Discussion

The pulp in a temporary tooth has a similar structure to that in a permanent tooth, but the time needed for it to reach full development is considerably longer for the permanent tooth than for the temporary tooth. The relationship with the periodontium was established, as in the case of the permanent tooth by the apical area, but also by the pulpal and periodontal accessory channels. The pulp in primary teeth does have similarities with that present in immature permanent teeth (capacity for recovery), but at the same time there are major differences (proportionally greater pulp volume with longer and more slender pulpal horns, closer to the enamel surface and therefore with much more frequent and rapid pulpal involvement than in the permanent dentition in cases of carious lesions).

Primary teeth at stage M (maturation) and immature permanent teeth have a similar physiology: incompletely formed roots,

developed vascularisation, a cellular potential, an ever-present possibility of repair: treatment is therefore directed at preservation of pulp vitality. At stage S (stability) the physiology of the temporary tooth is comparable to that of the permanent tooth, and our treatments are always directed at preserving the tooth.

Thus, as illustrated by the first clinical case, the aim is to keep the temporary tooth on the arch. Indeed, this tooth is necessary as a place-holder and guides the eruption of the adult tooth. To ensure that it stays for a long time and in order not to compromise the succedaneous tooth (absence of any root disease that could infect the pericoronal sac of the bud of the adult tooth) it is preferable that the pulp in the primary tooth should be healthy. Biodentine™ will help keep the stumps of pulp alive because the material is impervious. With physical and chemical properties similar to those of MTA® – accepted

as the material of choice for pulpotomies on temporary teeth –Biodentine™ presents the additional advantage of a shorter setting time.

Finally at stage R (rhizolysis/involution), the physiology is directed at replacement, pathologies are evolving rapidly and irreversibly – even with the use of conservative therapies – pulp involvement will direct treatment towards extraction (treatment indications are more limited). We shall not be seeking to keep the tooth and vitality.

Thus pulpotomy, which is the treatment most commonly used in temporary teeth, is indicated for asymptomatic primary teeth at stage M, stage S, or early stage R in the presence of pulpal inflammation confined to the cameral pulp, and < 2/3 tooth resorption.

The partial pulpotomy described in Clinical Case 2 is more frequently performed in immature permanent teeth (better recovery capacity of the dental pulp) whose vital pulp is asymptomatic, in order to be able to proceed with building and root maturation and the placement of the apical dentinocemental junction (apexogenesis).

A mature tooth with exposed pulp in a young subject who is not presenting any symptoms, a measured approach (less aggressive) with the aim of preserving pulp vitality in order that the

root walls can thicken (secondary apposition of dentin to achieve root build-up and maturation – a measure of the durability of the dental organ), to keep the tooth as intact as possible is performed as first intention.

According to Shayegan et al. in 2010 (partial pulpotomy and dentin bridge formation and pulp tissue reaction, WPC vs formocresol vs Biodentine™) and About et al. in 2010 (partial pulpotomy: preserving pulpal vitality), Biodentine™ induces dentin bridge formation, in the same manner as MTA®. Thus one may observe the apposition of tertiary dentin in direct contact with the capping material (protective role to prevent dentin reinfection and pulpal inflammation).

The action mechanism of calcium silicate cements such as Biodentine™ involves the release of calcium hydroxide with a basic pH like calcium hydroxide with, in addition, impervious dentin-material interfaces, as well as a dissolution resistance that does not involve any reintervention.

Despite the low clinical hindsight, on account of the recent availability of the material, the available studies in the animal model lead us to expect excellent results in terms of preserving pulpal vitality, dentin bridge formation and absence of complications (internal resorption, canal filling).

Conclusion

Within the framework of this case report we have dwelt on pulpal vitality-preserving therapies in paediatric dentistry in which the pulpal exposure was of carious origin and in two specific clinical situations; the material is proposed also for the restoration of deep carious lesions by indirect pulp capping in the context of filling using a sandwich technique and for partial pulpotomy following pulpal exposure in the context of trauma affecting a permanent tooth. In paediatric dentistry this material is going to offer the advantages of rapid

application in an emergency consultation without need for any preparation of the dentin surface, with the guarantee of imperviousness to avoid bacterial contamination (Dejou J. et al., 2005), and one that can be left in situ for up to 6 months.

The various studies available enable us right away to add this material to our everyday treatment armamentarium, with the results of long-term clinical studies due to be available in the coming months.

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Direct pulp capping with a bioactive dentine substitute

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Dr. Med. Dent. Markus Th. Firla

Direct exposure of the pulp as a result of preparation work during caries excavation or possibly due to trauma is something that repeatedly occurs in everyday clinical practice. Restorative protocols that preserve the long-term vitality of an affected - essentially healthy - pulp are dependent on a number of crucial factors. The most important one for the therapeutic outcome is the bioactive potency of the capping material directly covering the pulp exposure.

High biocompatibility and bioactivity

The dental material mineral trioxide aggregate (MTA) was introduced into restorative dentistry as early as the 1990s. Further refinement of the process of preparing a fine-grained mixture of up to 95% hydrophilic tricalcium silicate, tricalcium aluminate, tricalcium oxide and silicon oxide in an aqueous solution of calcium chloride and polycarboxylate, with the addition of zirconium dioxide as contrast medium, has made MTA an important material for endodontic treatments.

This is based on studies which showed that the biocompatibility – i.e. biological tolerability – of MTA is extremely good, since no signs of any threat of cytotoxicity, genotoxicity, or mutagenicity on body tissue, particularly the pulp tissue, were found. MTA is also safe as regards the absence of negative influences on cell differentiation or specific cell functions.

A material can be described as bioactive if it has a beneficial effect on living cells and interacts

with them in a biologically compatible manner. The bioactivity of a material is of interest and importance for dental practice particularly as regards its effect on the promotion of hard tissue formation on the pulp.

This is particularly useful when covering extremely thin pulp-facing layers of dentine, but especially on the direct capping of exposed pulp cavities, since the success of these endodontic protocols to preserve the vitality of the pulp depends crucially on whether the dental materials used:

- cause no postoperative sensitivity,
- support remineralisation of the dentine,
- initiate the formation of new hard tissue (dentine bridges, tertiary or repair dentine) and – not least of all –
- help to restore the general integrity of the dental pulp to guarantee its preservation.



Fig.1: Lower first molar of a 42-year-old man. Despite the complex damage the tooth showed a normal positive reaction to cold stimulus testing using a cotton wool pellet cooled with ice spray and was on the whole otherwise clinically normal.



Fig.2: The targeted removal of the insufficient amalgam filling and careful clearance of all softened areas of dentine meant that opening of the pulp cavity was unavoidable despite using the least invasive approach possible with an excavator.



Fig.3: The obviously healthy and asymptomatic pulp makes possible the use of direct pulp capping as sole endodontic measure. The first step here is disinfection of the entire cavity for 2 minutes with polyhexanide/betaine.



Fig.4: The cavity after disinfection. The surface of the exposed pulp can be seen clearly. Now it is necessary to close the dentine wound in a pulp-sparing, absolutely germ-proof manner that induces tertiary or repair dentine.

The strikingly positive effect of such calcium silicate-based products, like the dentine substitute Biodentine™ manufactured by Septodont described as an example here, is based - in simplified terms - on the release of

calcium hydroxide ions in the setting reaction. This reaction is associated with the presence of an extremely alkaline environment with a pH of about 12.5 which stimulates the pulp tissue to form reactive dentine.

Antibacterial properties

Because of the manifest alkalization of the environment, this high pH also exerts a clear inhibitory effect on microorganisms. In addition, the alkaline change demonstrably leads to the disinfection of adjacent hard- and soft-tissue structures. These two effects are, according to relevant scientific investigations with calcium silicate materials such as Biodentine™, very

pronounced and have a demonstrable impact: not only dentine damage to teeth with varying areas of exposed pulp with noncarious causes, such as accidental pulp opening or direct abrasive trauma, can be treated; extensive carious defects caused by bacteria can also be properly excavated and given specific treatment.



Fig.5: The material of choice for this is – in the author’s view and experience – Biodentine™. A bioactive material based on mineral trioxide aggregate (MTA) which has all these positive properties.

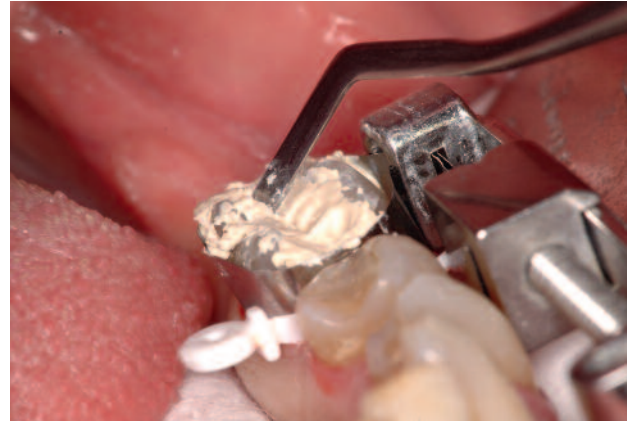


Fig.6: The material that can be used as a dentine substitute can be deployed in a wide range of restorative endodontic procedures and can even, according to the manufacturer, be used for “complete closure” of a cavity for up to 6 months.



Fig.7: With a working time of about 12 minutes and its smooth, pasty consistency, Biodentine™ is to be preferred to all previously known materials for MTA-based endodontic uses.

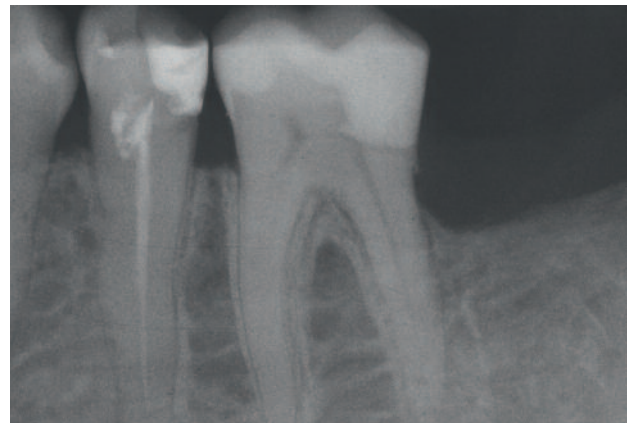


Fig.8: The X-ray taken immediately after completion of the cavity treatment. The addition of zirconium dioxide gives good radiopacity. The tightness of the seal and the cap on the oblique pulp chamber opening are clearly visible.

Best choice for the pulp

A manifestly healthy pulp can be treated clinically using a number of materials. Calcium hydroxide preparations are still the gold standard, since the antibacterial and dentine-inducing action of calcium hydroxide is undeniable. However, the chemical instability and mechanical weakness of pure calcium hydroxide and all preparations based on calcium hydroxide are major drawbacks. Methods in which adhesives and composites are used for the direct capping of exposed pulp can be regarded as having comparable disadvantages. These drawbacks are however

due mainly to the possible irritation of the exposed pulp by the unavoidable acid etching of the adhesives and the toxicity of the monomers which triggers what ultimately becomes manifest inflammation of the pulp.

If glass ionomer cements are used for direct capping, their chemical stability, mechanical strength, adhesive anchoring to the dentine and the threat of toxicity should not be regarded as weaknesses, but they lack the required and particularly necessary dentine-forming effect that is to be expected.



Fig.9: The molar with its complete Biodentine™ treatment 6 weeks after direct pulp capping. The border seal and integrity of the dentine substitute are clinically impeccable.

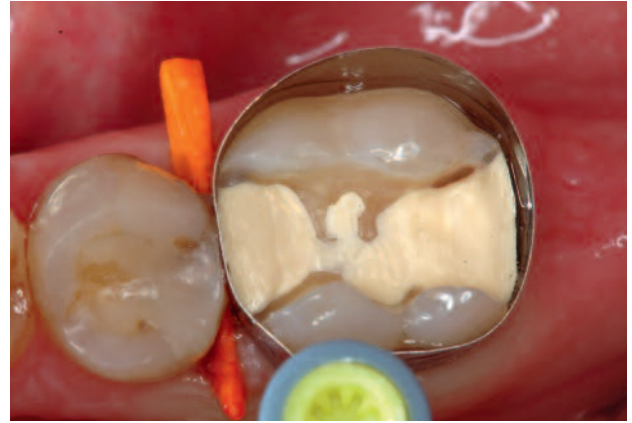


Fig.10: Since the molar continued to be completely symptom-free during this period and the cold stimulus test again produced a normal positive result, it was decided, by agreement with the patient, to now give the tooth a permanent composite filling.

As already emphasized, calcium silicate cements give off – during the setting and for a relatively long time thereafter – particularly large quantities of calcium hydroxide ions, so that they are extremely suitable for treatment of the exposed pulp. They also have physical properties comparable to those of dentine.

The specific properties of Biodentine™ presented as an example here are:

- The elastic modulus, at 22.0 GPa, is very similar to that of dentine at 18.5 GPa.
- The compressive strength of about 220 MPa is equivalent to the average figure for dentine of 290 MPa and is much greater than that of glass ionomer cements.
- The microhardness of this dentine substitute, at about 60 HVN is virtually the same as that of natural dentine.
- Acid resistance in acid erosion tests showed that the tricalcium silicate material presented here has less surface disintegration than glass ionomer cements. There was no abrasion at all in artificial saliva. There was however deposition of apatite-like calcium phosphate crystals on the surface. This phenomenon allows conclusions to be drawn about a progressively improving interface between the dentine substitute Biodentine™ and the

adjacent phosphate-rich hard tooth substance.

- “Alkaline etching” produces reliable seal. Biodentine™ can be described as a hard tooth substance-adhesive restoration material. According to the investigations of the holder of the chair in biomaterials and restorative dentistry at the Guy’s Hospital Dental Institute at King’s College, Prof. Timothy Watson, the micromechanical adhesion of this tricalcium silicate material is in particular caused by the alkaline effect during the setting reaction (already described in the text above). The extremely high pH causes organic tissue to dissolve out of the dentine tubuli – unlike on the breakup and dissolution of the inorganic constituents of natural hard tooth substance in classic “conditioning” of tooth enamel and dentine with acids. – The alkaline environment at the boundary area of contact between this tricalcium silicate material and the hard tooth substance thus opens a path via which the dentine substitute mass can enter the exposed openings of the dentine canaliculi. This enables Biodentine™ to be keyed to the dentine by means of innumerable microscopic cones, creating a stable anchorage with a sealing, bacteria-tight effect, without the need for prior treatment with irritants that compromise the pulp.



Fig.11: Since the pulp-facing portion of the dentine substitute could – according to the manufacturer’s information – be left in place as a “foundation”, an adhesive “cover filling” with N’Durance® (Inc) was inserted.

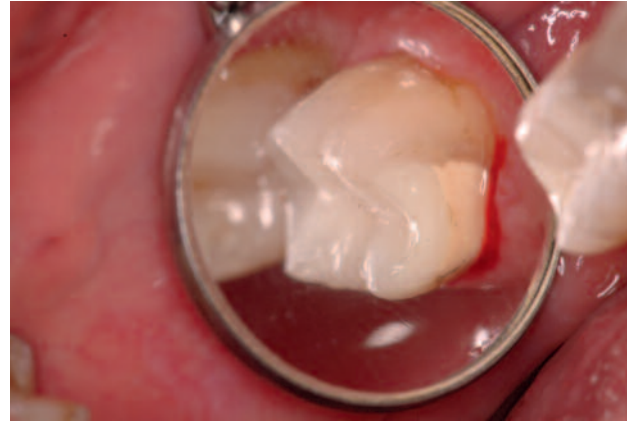


Fig.12: Distal view of the filled tooth (in a mirror). The sound bond of Biodentine™ and N’Durance® both with one another and with the hard tooth substance itself is clearly visible.

Summary

Mechanically stable capping of the exposed pulp to preserve the health of the pulp or, in cases of reversible disease, to decisively promote complete recovery, can, on the basis of the emerging knowledge about clinical use and materials, best be done using calcium silicate-based materials. The handling

difficulties and relatively long setting time of such refined Portland cements have been markedly improved for successful routine use in dental practice of the latest materials available as capsule systems, such as the calcium silicate dentine substitute Biodentine™ which has been available on the dental market for some time.

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Biodentine™

A dentin substitute for the repair of root perforations, apexification and retrograde root filling

Dr François Bronnec, DDS, MSc

Introduction

Initially proposed for retrograde obturation of root canals using MTA in endodontic surgery, calcium silicate cements have gradually become the material of choice for the repair of all types of dentinal defects creating communication pathways between the root-canal system and the periodontal ligament (Bogen and Kuttler 2009, Parirokh and Torabinejad 2010). With their proven biocompatibility and ability to induce

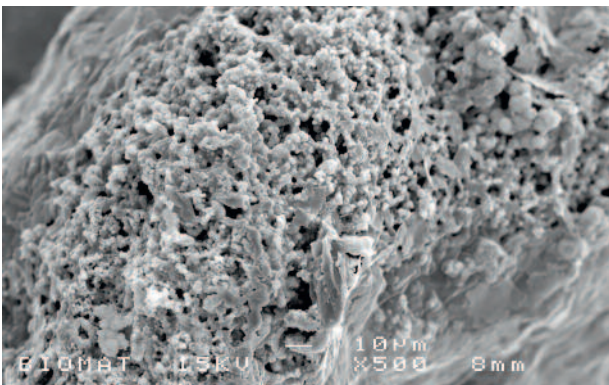


Fig.1: Microscopic view of calcium-phosphate precipitates formed when the material is exposed to biologic fluids (MEB, x 500).

calcium-phosphate precipitation (fig.1) at the interface to the periodontal tissue, they play a major role in bone tissue repair (Tay et al. 2007, Reyes-Carmona et al. 2009, Torabinejad and Parirokh 2010). The high quality of the material-dentin interface which improves over time secures long-term clinical success and reduces

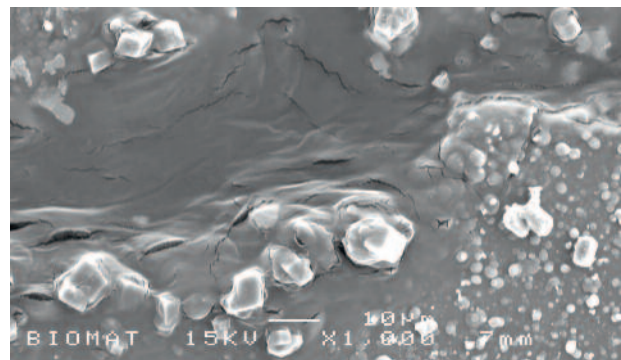


Fig.2: Quality of the material-dentin interface showing perfect adaptation and marginal seal of the filling (MEB, x 1000).

the risk of marginal percolation (fig.2). The main drawbacks of this class of materials so far have been slow setting kinetics and complicated handling, which rendered these technique-sensitive procedures even more difficult and restricted their use to specialists (Parirokh and Torabinejad 2010).

Biodentine™ cement is part of a new approach seeking to simplify clinical procedures. A modified powder composition, the addition of setting accelerators and softeners, and a new predosed capsule formulation for use in a mixing device, largely improved the physical properties of this material making it much more user-friendly (Wang et al. 2008, Wonkornchaowalit and Lertchirakarn 2011).

Clinical cases

Repair of a perforation of the pulp floor iatrogenically induced during retreatment (Fig. 3a to g)

A female patient presented for consultation after complications had occurred during retreatment. The left upper first molar exhibited periodontal symptoms, and radiography showed periapical lesions at the mesio-buccal and palatal roots resulting from previous insufficient management, as well as radiolucency at the furcation without attachment loss. Since the tooth exhibited considerable coronal decay, the temporary filling was removed to assess the viability of the remaining tooth structure. Iatrogenic pulp-floor perforation was diagnosed, and with the patient's consent an attempt was made to preserve the tooth by sealing the endo-periodontal communication.

Retreatment was performed in two sessions, with intracanal medication between sessions. After removal of the filling and instrumentation of the root canal, the perforation lesion was debrided with ultrasonic instruments and a

calcium hydroxide intracanal dressing was placed to control periodontal inflammation.

After 7 days, the tooth was without symptoms and the canals could be dried. The session started with repair of the perforation to avoid any risk of contamination with endodontic cement when obturating the canals. The canal orifices were isolated with cotton pellets, and the dentin defect was filled with 2 layers of Biodentine™ using an amalgam carrier. The material was then adapted to the cavity with a cotton pellet without pressure. Once the material had set any excess material was stripped off with a curette before removing the cotton pellets and filling the root canal in the same session. At the end of the session, the hardened material was shaped with a bur to reproduce the pulp floor convexity for the future restoration of the tooth. The copper band was removed and replaced by a temporary metal cap luted with glass ionomer cement. Follow-up at three months showed no clinical signs, and the X-ray confirmed complete healing of the apical and furcation lesions.



Fig. 3a: Pretreatment radiograph.

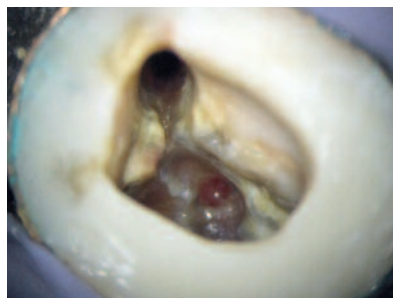


Fig. 3b: Microscopic view of the perforation site.



Fig. 3c: Calcium hydroxide intracanal medication.

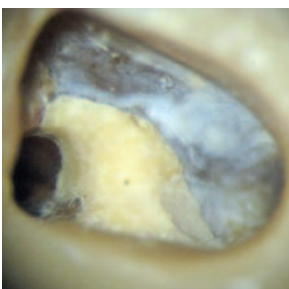


Fig. 3d & e: Repair of the perforation before obturation of the root canal.



Fig. 3f: Posttreatment radiograph

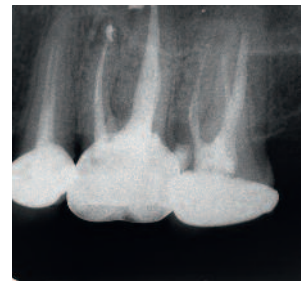


Fig. 3g: Radiograph at 3 months' follow-up showing complete healing.



Fig. 4a: Pretreatment radiograph.



Fig. 4b: Perforation site viewed through the surgical microscope.

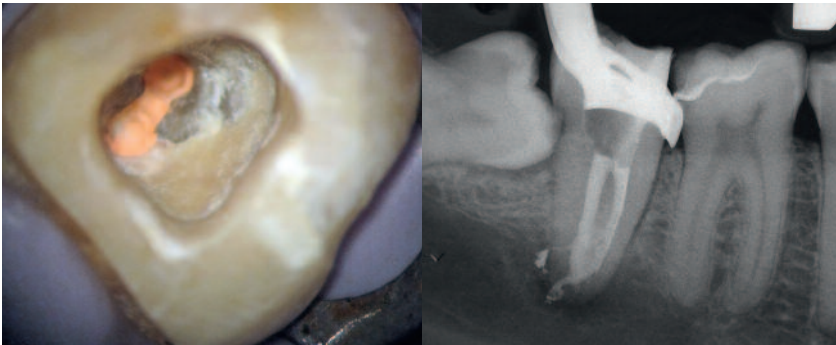


Fig. 4c & d: Microscopic view of the material in place after setting, and control X-ray film..



Fig. 4e: Posttreatment radiograph showing completed coronal restoration.

Repair of a recent perforation caused during primary endodontic treatment of a necrotic tooth (Fig.4a to e)

A male patient was referred for emergency treatment by his dentist who could not account for unexpected bleeding when trying to find the mesio-buccal canal of the right lower 2nd molar. The tooth was pain-free, probing depth was normal. Radiographic examination revealed a periapical lesion, and the fusion of the mesial and distal roots of this second molar suggested a C-shaped canal.

After removal of the temporary filling and pre-endodontic restoration of the crown, the access cavity was extended for complete view of the

pulp floor. Inspection revealed an accidental perforation of the pulp floor. The tooth being only slightly decayed, it was decided to carry out a complete preparation of the root canal system before managing the endo-perio communication. As the site of the perforation was at a safe distance from the canal orifices, the root canals could be filled before repair of the perforation. Repair of the dentin defect was then achieved by placing an increment of Biodentine™ with an amalgam carrier and adapting it to the wall with a cotton pellet. Once the Biodentine™ had set hard, excess material was eliminated with a curette. The access cavity was filled with a 3 mm layer of glass ionomer cement covered by composite material.

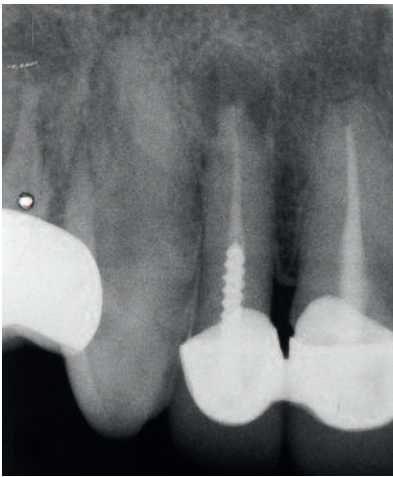


Fig. 5a: Initial radiograph before retreatment.



Fig. 5b: Radiograph at 3 months' follow-up showing absence of healing.



Fig. 5c: Microscopic view of the retrograde obturation.

Endodontic surgery after failure of orthograde endodontic retreatment (Fig. 5a to e)

A male patient presented with symptoms that persisted despite previous orthograde retreatment. The right upper lateral incisor was restored with a post and core buildup, and a temporary crown has been in place for a few months. Radiographs before retreatment and 3 months later showed a persistent periapical lesion and inflammatory root-end resorption.

Since obturation of the canal system seemed radiographically adequate, surgical retreatment was opted for.

After raising a full-thickness flap using an incision in the attached gingiva, access to the defect was obtained with a tungsten-carbide bur in a turbine handpiece with water spray. The lesion was curetted before resection of the apical 3 mm of the root. After verifying the absence of any root fractures, the gutta percha and cement filling was removed from the root canal up to the level of the root post. The canal was instrumented to 6 mm using ultrasonic tips (EndoSuccess Apical Surgery Kit, Actéon-Satélec, Mérignac, France). After decontamination and drying of the root cavity, retrograde obturation was completed placing 3 layers of Biodentine™ with the use of a syringe-mounted carrier system (MAP-system, PDSA,

Vevey, Switzerland). The successive portions of material were deposited in the root end cavity and adapted to the wall with root canal pluggers. After hardening of the material, a red (fine) diamond bur was used to surface the root cross-section and eliminate any excess material. Bleeding into the bone cavity was ensured before repositioning and closure of the flap with interrupted synthetic sutures (polypropylene 5/0 and 7/0, B Braun, Germany).

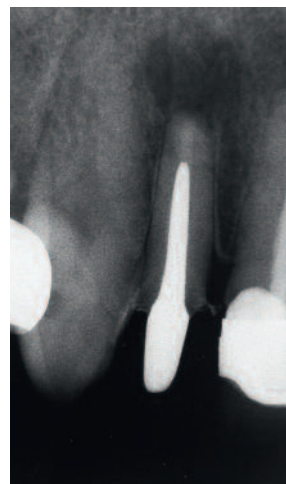


Fig. 5e: Radiograph at 3 months' follow-up showing healing in progress.

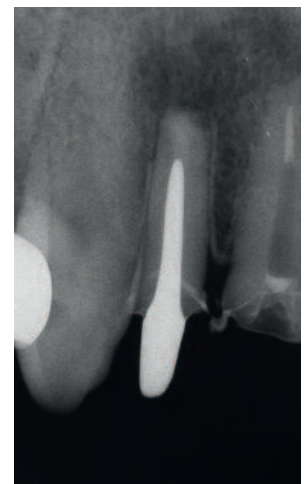


Fig. 5e: Radiograph at 3 months' follow-up showing healing in progress.

The patient was seen after 48 hours for suture removal and to make sure there were no post-op complications. Upon clinical and radiographic examination 3 months later, the tooth presented no symptoms and showed radiographic signs of an on-going healing process.

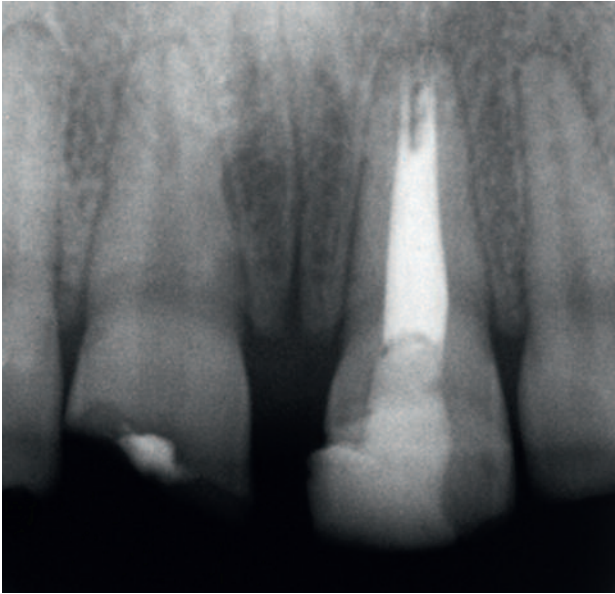


Fig. 6a: Posttreatment radiograph

Apexification of an immature tooth (Fig. 6a to b)

A young male patient presented with dental trauma resulting in coronal fracture of the right upper central incisor. Initial examination revealed that the pulp had been capped in emergency treatment at the hospital. Radiographically an insufficient root filling was detected in the left upper central, which also showed incomplete root growth with apically diverging walls. It was therefore decided that apexification was indicated. Both teeth were to be treated in the same session, while the restoration of the tooth was to be left to the referring dentist.

Following removal of the root-canal filling from the left upper central, the endodontic treatment plan was to fill the apical part of the canal after



Fig. 6b: Control X-ray before placement of conventional restorations.

cleaning and decontamination with a sodium chlorite solution. Shaping was limited to the coronal third of the canal (Gates drills) to facilitate direct instrument access to the foramen.

A first increment of Biodentine™ was inserted into the canal using a curved needle of the largest diameter fitting into the canal (MAP-system, PDSA, Vevey, Switzerland). The material was then delicately pushed towards the apex with a root-canal plugger. Several increments were required to form a plug of adequate thickness (> 4mm). The material was adapted to the walls by applying indirect ultrasonic vibration through an ultrasonic tip placed on the plugger touching the material. After verifying that the material was hard-set, the patient was sent back to his dentist for further treatment and conventional restoration.

Conclusion

Validated experimentally (Bronnec 2009, Laurent et al. 2008, Valyi 2008), the efficacy of Biodentine™ as a dentin substitute is yet to be clinically proven for each of its therapeutic indications. The short and medium-term results of clinical studies conducted in endodontic as

well as restorative fields of application are in the re-evaluation phase, and will be published as evidence in scientific articles in a few months. The first results observed in a private practice since the material was launched a year ago, are extremely promising.

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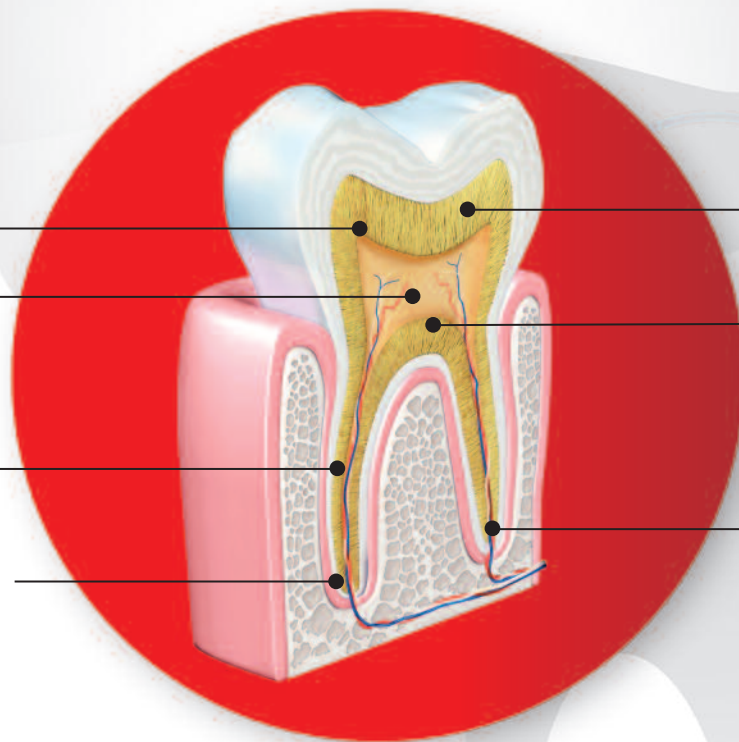
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